XXVII. *Some farther Conſiderations on the Influence of the Vegetable Kingdom on the Animal Creation.* *By* John Ingen-houſz, *Counſellor to the Court, and Body Phyſician to the Emperor, F. R. S. &c.*

Read June 13, 1782.

UPON being informed, a few months ago, as well by private letters as from the Critical Review, that my doctrine was quite over-turned by the fifth volume of Dr. PRIESTLEY, and by an experiment quoted in the book of Mr. CAVALLO on Air; I invited ſome of my friends here to aſſiſt at ſome deciſive experiments, of which I will here give an exact account. I told them the whole reſult which was to be expected from them, if my ſyſtem was founded on nature, explaining to them before-hand the theory of theſe reſults, and promiſing, at the ſame time, that, if the reſult ſhould fail, I ſhould myſelf be the firſt to diſcredit my own ſyſtem. I had the ſatisfaction to convince them that the reſult did fully anſwer my prediction and expectation. Theſe experiments are the following, all made in a hot-houſe of the Botanical Garden in the winter of 1782.

I expoſed to the ſun-ſhine ſix globular glaſs veſſels, each containing about 160 cubic inches of ſpace, all filled with pump-water, which was boiled during more than two hours, and poured quite hot into the glaſs veſſels, on purpoſe to prevent any acceſs of air to the water.

Exp. I. In two of theſe veſſels I put as much of the *conferva rivularis* (a water plant, claſſed by LINNÆUS amongſt the *cryptogamia*) as was ſufficient to take up the ſpace of about an inch ſquare.

Exp. II. In the two next veſſels I ſuſpended by threads tied to bits of cork, ſome pieces of woollen and ſilk cloth of different colours, as white, ſcarlet, green, and brown, having previouſly wetted them in ſome boiled water, on purpoſe to free them from all air.

Exp. III. In the two remaining veſſels I placed nothing at all.

Exp. IV. In another veſſel of the ſame form and ſize I put ſome of the *conferva rivularis*, and filled it with pump water.

All theſe globular veſſels were inverted, with their orifices immerſed in veſſels filled with quickſilver, for the purpoſe of preventing effectually any communication between the contents of the veſſels and the atmoſphere.

Reſult of experiment I. The firſt two days neither of the veſſels contained any air, and even the ſmall quantity of air, which here and there adhered in the form of a bubble to the fibres of the vegetable when it was ſhut up in the veſſel, had entirely diſappeared. The third day, in the morning, ſome air bubbles began to riſe from every part of the *conferva* in both glaſſes; and in the afternoon of the ſame day, a great quantity of air bubbles roſe continually from it. I took at that time the vegetable out of one of theſe veſſels. I plunged a wax taper, juſt extinguiſhed, into the orifice of this veſſel, on purpoſe to ſee whether the air, already extricated from the *conferva*, was dephlogiſticated or not. The wax taper took flame immediately with an uncommon ſplendour. After this I poured the half of the water from the globular veſſel into a common bottle, and corked it. I inverted this bottle afterwards

in an earthen veſſel filled with boiled water. I placed this apparatus near the fire till the water in the bottle began to boil; after which I cooled the whole, and found a good quantity of air collected in the bottle, which air proved to be dephlogiſticated. When I drew the vegetable out of the glaſs veſſel I obſerved the water to ſparkle almoſt like Seltzer water, or like water impregnated by art with fixed air. The vegetable which was ſtill kept in the ſecond bottle of exp. I. continued to yield air in the ſun-ſhine, till it ceaſed to throw up any more air, towards the ſeventh or eighth day of its being ſhut up in the veſſels. When, after this time, this globular veſſel was ſhook, the water became full of ſmall air bubbles, which for the moſt part roſe to the inverted bottom of the veſſel, great part of them ſettling upon the vegetable, which appeared all covered with them. This ſparkling air, which became viſible by ſhaking the glaſs, could not but be air originally produced by the *conferva*, and ſo looſely joined with the water, that it diſengaged itſelf in a great meaſure from it by the motion of the veſſel. After the tenth day the vegetable began to appear withered, grew yellow, and began to die. I found about eight cubic inches of dephlogiſticated air collected in the veſſel. This proved to be of a very eminent quality, its goodneſs being of 352°; that is to ſay, that from a mixture of one meaſure of this air, and as many meaſures of nitrous air as were neceſſary to complete the full ſaturation, there were deſtroyed three meaſures and $\frac{52}{100}$ of a meaſure, the teſt being made with Abbé FONTANA's Eudiometer, employed in the manner deſcribed in my book upon Vegetables, p. 278. *et ſeq.* The quality of this air was ſuperior to that of any air I ever got from this plant in freſh pump water, its goodneſs proving, in general, to be from 260 to 330°, in the hot-houſe; this was during the winter, for I never had been

been able to obtain ſuch fine air from this vegetable in the ſummer*; the reaſon of which I will explain elſewhere.

Theory of exp. I. Boiled water, having loſt its air, is very much diſpoſed to imbibe it from all bodies which contain this fluid; and therefore, during the firſt day or two of its expoſure to the ſun-ſhine with the vegetable, this water abſorbed all the air which the plant emitted; and even that which had remained entangled between the fibres of the vegetable when it was immerſed in this water. The water being at laſt ſaturated with this air could take up no more; and therefore, whatever air, after this ſaturation, came forth from the vegetable roſe to the top of the veſſel. The quantity of this dephlogiſticated air was ſmaller than that which an equal bulk of the ſame plant commonly yields in freſh pump water, becauſe a great deal of air was at firſt taken in or abſorbed by the boiled water; which abſorption does not happen, or at leaſt is not ſo great,

* By continuing to make experiments, during the whole winter, in the hot-houſes of the botanical garden, I found that the *conferva rivularis* yielded dephlogiſticated air of a much ſuperior quality to that I had ever been able to get from it in the ſummer, in the open air; whereas thoſe plants, ſuch as the *agave Americana*, *cactus triangularis*, &c. which yielded in the ſummer the beſt air, did ſcarce yield any in the winter (and that of a quality ſcarce better than common air) though placed next to the *conferva*. The quantity of dephlogiſticated air I got in the winter from the *conferva* was ſo great, that as much of this vegetable as occupies about the ſpace of one cubic inch commonly yielded from 12 to 16 cubic inches of this air in the ſpace of three or four days, when the ſun did ſhine, the quantity of pump-water being about 160 cubic inches. The green matter which Dr. PRIESTLEY mentions as ſpontaneouſly produced from pump-water, gave in the winter alſo a tolerable quantity of dephlogiſticated air, of a good quality, though not ſo fine, or in ſuch large quantities, as it is uſed to give in the ſummer. It ſeems to be a general rule, that the greater the quantity of air obtained from vegetables in the ſun is, the better is its degree of goodneſs.

when

when pump water is uſed, as this water is always nearly ſaturated with air. The air, thus obtained in boiled water, was of a finer quality than that commonly obtained by the ſame means in pump water; becauſe this air, being entirely free of air diſengaged from freſh water, muſt of courſe be ſo much the purer dephlogiſticated air. The water of the firſt veſſel, and which was taken out of it as ſoon as air bubbles began to riſe from the plant, ſparkled like Seltzer water, and yielded by heat dephlogiſticated air, becauſe it was then already ſaturated with dephlogiſticated air iſſuing from the vegetable. The water of this veſſel being ſhook, after the vegetable ceaſed to throw up any more air in a viſible way, ſtill continued to ſparkle; becauſe, though the vegetable by loſing gradually its vigour, was at laſt no more able to throw up air in viſible bubbles, yet it had ſtill enough of its vital power left to keep the water ſaturated with dephlogiſticated air, ſo as to ſparkle when ſhook. This vegetable, continually robbing the water of its natural air, found at laſt nothing more in it to ſupport its life, and therefore at laſt languiſhed and periſhed; which it did ſo much the ſooner, from the contact of the dephlogiſticated air, with which the water was impregnated, and to which the vegetable had been all that time expoſed, having hurt its conſtitution (it is well known, that plants die in dephlogiſticated air) and thus haſtened its death. The ſparkling quality of the water did not ceaſe entirely till the vegetable was quite deprived of its life. The water began to ſparkle every day very briſkly, by being ſhook after the apparatus had been expoſed an hour or two to the ſun-ſhine, during the time the vegetable was in its full vigour, and ceaſed to do ſo ſome time after ſun-ſet, or after the apparatus had been withdrawn from the ſun's light; becauſe this vegetable, like all others, elaborates no dephlogiſticated air but by the

influence of the ſun; and becauſe this air, being but looſely united with the water, diſengaged itſelf again from it, and roſe to the inverted bottom of the veſſel. The water being thus deprived of the dephlogiſticated air, ceaſed to ſparkle any more, till it became again ſaturated with it, after the apparatus had been expoſed again, during ſome time, to the influence of the light.

Reſult of exp. II. No air at all was produced in the veſſel containing the pieces of cloth, during three weeks expoſure to the ſun-ſhine.

Theory of exp. II. Boiled water, having loſt its air, could yield none, at leaſt till after a long time, when ſome degree of corruption took place in the animal ſubſtance, *viz.* the pieces of cloth.

Reſult of exp. III. Not an atom of air has appeared in this veſſel, though it ſtood about two months upon the ſame place.

Theory of exp. III. Boiled water having no air, the ſun could extricate none from it.

Reſult of exp. IV. the *conferva* began to yield air bubbles the very ſame day, a little while after its expoſure to the ſun. The next day it threw up an immenſe quantity of them. The fifth day it begun to throw up leſs, and ceaſed entirely about the ſeventh day, when the quantity of about fourteen cubic inches of dephlogiſticated air, of an excellent quality, though leſs fine than that obtained in exp. I. was collected. The water ſparkled, as does Seltzer water, by the veſſel being ſhook. This water being expoſed to the fire, in an inverted veſſel, yielded a good quantity of air, which was ſo far dephlogiſticated as to be able to kindle a wax taper juſt extinguiſhed. After the tenth day the vegetable began to die.

Theory

Theory of exp. IV. The vegetable threw up very ſoon air bubbles, becauſe this water, being in its natural ſtate, and thus ſaturated with air, could not abſorb much of the air iſſuing from the vegetable, which air muſt, of courſe, ſoon riſe up in viſible bubbles. A great deal more air was collected than in exp. I. becauſe leſs of the air iſſuing from the plant was abſorbed by this water than in exp. I. The air obtained was not ſo good as that obtained in exp. I.; becauſe the air in this experiment was ſomewhat infected by the air iſſuing from the water, which was but common air. The water ſparkled when the veſſel was ſhook, becauſe this water, though it had probably loſt ſome of its own air, yet had aſſumed a great deal of air from the plant *, which air diſengages itſelf from the water very eaſily, juſt as fixed air does; the more ſo when the water is moved.

* It ſeems, that dephlogiſticated air has by no means ſuch a ſtrong attraction to water, in other words, has not ſo much affinity with it, as common air has: it appears to be but looſely united with water, and quits it very eaſily by the water being ſhaken, or even though the water be kept quiet. May not this quality be looked upon as a providential one? for thus the dephlogiſticated air, produced by water plants, is continually emitted by the water, and diffuſed through the common ſtock; and for this reaſon the water, when ſhook during the day-time, always ſparkled as champaigne; becauſe at that time the water was always kept ſaturated by the dephlogiſticated air, iſſuing continually out of the vegetable. But the water ceaſed to ſparkle, after having been withdrawn from the ſun-ſhine during ſome hours; becauſe the dephlogiſticated air, with which the water was ſaturated during the day-time (ſuppoſing the apparatus to be kept expoſed to the ſun) being but looſely united with the water, diſengaged itſelf gradually from it, and roſe to the top of the veſſel. The ſparkling quality of this water returned after the veſſel had been expoſed afreſh to the ſun; becauſe the vegetable, reſuming in that expoſition its daily operation, communicated a freſh ſupply of dephlogiſticated air to the water. This ſparkling quality returned every day, as long as there remained any life in the vegetable; after which the water ſparkled no more (though ſhook ever ſo much) either by day or in the night.

This water yielded, by heat, true dephlogiſticated air; whereas the ſame water, when it has not been expoſed to the action of a vegetable, yields by heat nothing but common air. The reaſon of it is, that the air elaborated by the plant, with which this water was ſaturated, was real dephlogiſticated air. The vegetable at laſt languiſhed and began to die, becauſe the water was impregnated with dephlogiſticated air, which being an excrement of the plant is hurtful to its conſtitution. Beſides, this water had at laſt loſt the moſt part of, or perhaps all, its own ſtock of common air; and with this all the nutritive nouriſhing and phlogiſtic particles, which were taken in by the plant, and was therefore become leſs fit to keep up vegetable life.

All theſe experiments were repeated frequently, and always with the ſame general reſults *.

I think the abovementioned facts will be looked upon as quite ſufficient to put my doctrine out of all farther queſtion. I have many more facts, perhaps equally demonſtrative with thoſe juſt deſcribed; but, as this paper is already too long, I will keep them for ſome other opportunity. However, I cannot forbear making ſome farther remarks by which the point in queſtion may be ſtill farther illuſtrated.

If it was the water, and not the vegetable, which yielded the dephlogiſticated air; and thus, if the reaſon why water plants and the green matter ceaſe at laſt to throw up more air (if the

* That air is thrown out of living vegetables expoſed to the ſun-ſhine, was already obſerved by the rev. Dr. HALES, as may be ſeen in vol. I. of his Statical Eſſays, p. 110. The apparatus which he uſed for this experiment is repreſented by fig. XVII. plate VII. But this ineſtimable philoſopher, not even ſuſpecting that this air was of a peculiar nature, did not collect it. BOYLE obtained much air from vegetables *in vacuo*.

water is not renewed) is, that the water being at laſt exhauſted of its air can yield no more, it would neceſſarily follow, that the water, thus ſuppoſed to be deprived of air, ſhould be ſimilar to diſtilled or boiled water; but it is quite the reverſe. This very water, inſtead of being exhauſted of air, gives evident ſigns of being over ſaturated with it. It ſparkles almoſt as champaign does, when ſhook by daytime in the ſun; and it will, when it is at that time ſeparated from the vegetable, yield by itſelf in the ſun, but more ſo by the fire, a good quantity of dephlogiſticated air. The reaſon why the green matter ceaſes at laſt to yield more air is therefore by no means becauſe the water is exhauſted of air; but, on the contrary, becauſe it is too much ſaturated with it, and that with an air hurtful to vegetable life, and becauſe this water has at laſt loſt its own natural air, and together with this air the nouriſhing and phlogiſtic particles which are neceſſary to keep up the full vigour of plants.

If it was the water, and not the vegetable, which furniſhed the dephlogiſticated air, why ſhould the air bubbles not ſettle indifferently on either ſurface of the leaves? In this ſuppoſition, how could that admirable regularity be accounted for, by which all the leaves of a vine and a lime-tree are firſt covered with air bubbles on the under ſide, and all the leaves of *lauro-ceraſus*, at the upper ſurface, whichever ſurface of the leaves is expoſed to the rays of the ſun? Why ſhould the air always ſettle on moſt leaves in the form of bubbles, but never ſo upon the leaves of the *tropæolum majus*, at leaſt during the firſt hours, but always in the form of bags, adhering to the upper edge of the leaves, and detaching themſelves when they are grown to a certain

ſize,

ſize, which never happens with leaves of a vine or lime-tree *; whereas the green ſtalks of this plant (the *tropæolum majus*) are at the ſame time all covered with ſeparate air bubbles? More of theſe remarkable appearances in different plants are to be ſeen in the third ſection of my book on Vegetables.

If the dephlogiſticated air, obtained by means of vegetables in water, was air depoſited from the water, and purified of its phlogiſton, by remaining, during a certain time, in contact with the vegetable, it would follow, that this air would be ſo much the purer the longer it remains in contact with the vegetable; but it is quite the reverſe. The air obtained from the leaves of a vine, to which the air bubbles ſtick a long while before they detach themſelves and riſe up, is never by far ſo much dephlogiſticated as is the air obtained from ſome American plants, out of which the air ruſhes almoſt all in continual ſtreams, as ſo many ſprings, not remaining a ſingle moment upon the leaves. The difference of both airs is ſo great, that I never got dephlogiſticated air from leaves of a vine, lime-tree, and ſuch like, whoſe goodneſs ſurpaſſed 260° (it is commonly a little above 200°); whereas I got commonly, from the above mentioned American plants, an air whoſe goodneſs was of above 300°, ſometimes even of above 350°, in a very fair day, this air being put to the teſt, according to the manner which I have deſcribed before †.

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* I have explained the reaſon of this ſingularity in that plant, in my book, where it is mentioned by the name of *naſturtium indicum*.

† The *ſempervivum tectorum*, which grows almoſt every where upon the roofs of houſes, gives alſo a very great quantity of dephlogiſticated air of an eminent quality. It ſhould ſeem, that all fleſhy plants particularly excel in the quality of yielding fine dephlogiſticated air, and a great quantity of it. The *agave Americana*

If it was the water, and not the plant, which yielded the dephlogiſticated air, the quantity of air obtained would bear, in general, a proportion to the quantity of the water employed; but this is by no means the caſe. The quantity of air bears a proportion to the bulk of the vegetable much more than to the quantity of the water. This is very eaſily to be obſerved with ſome of the above mentioned American plants. It ought to be always obſerved, that if too many leaves are crowded together, they ſhade one another too much; and therefore, in this caſe, the quantity of air obtained will be proportionably leſs, and its quality worſe.

Again: if the dephlogiſticated air, obtained from plants in water, was air diſengaged from the water, it would follow, that a plant ſhut up in a tranſparent glaſs veſſel without any water would yield no air at all, nor increaſe the quantity of air ſhut up with the vegetable. The following experiment, I think, will be ſufficient to convince any one that this is far from being the caſe. I placed in a glaſs tube, hermetically ſealed at one end, a piece of an American plant, called *cereus*; the extremity of this piece, where it was cut from the plant, was tightly ſqueezed in a ſmall glaſs veſſel, in which only as much water was kept as ſeemed to be required to keep the *cereus* in full vigour. I ſmeared the vegetable, and the orifice of the glaſs veſſel all around with ſoft wax, ſo that all communication between the air within the tube and the water within the ſmall veſſel was cut off. I placed this tube inverted in a veſſel filled with quickſilver, keeping a column of ſome inches of

ricana gives ſuch a prodigious quantity of dephlogiſticated air, that, in a fair day, I often got from one ſingle leaf above 150 cubic inches of this air, of the fineſt quality. The *cactus triangularis*, *cereus*, *ſempervivum arborum*, and many others give no leſs air.

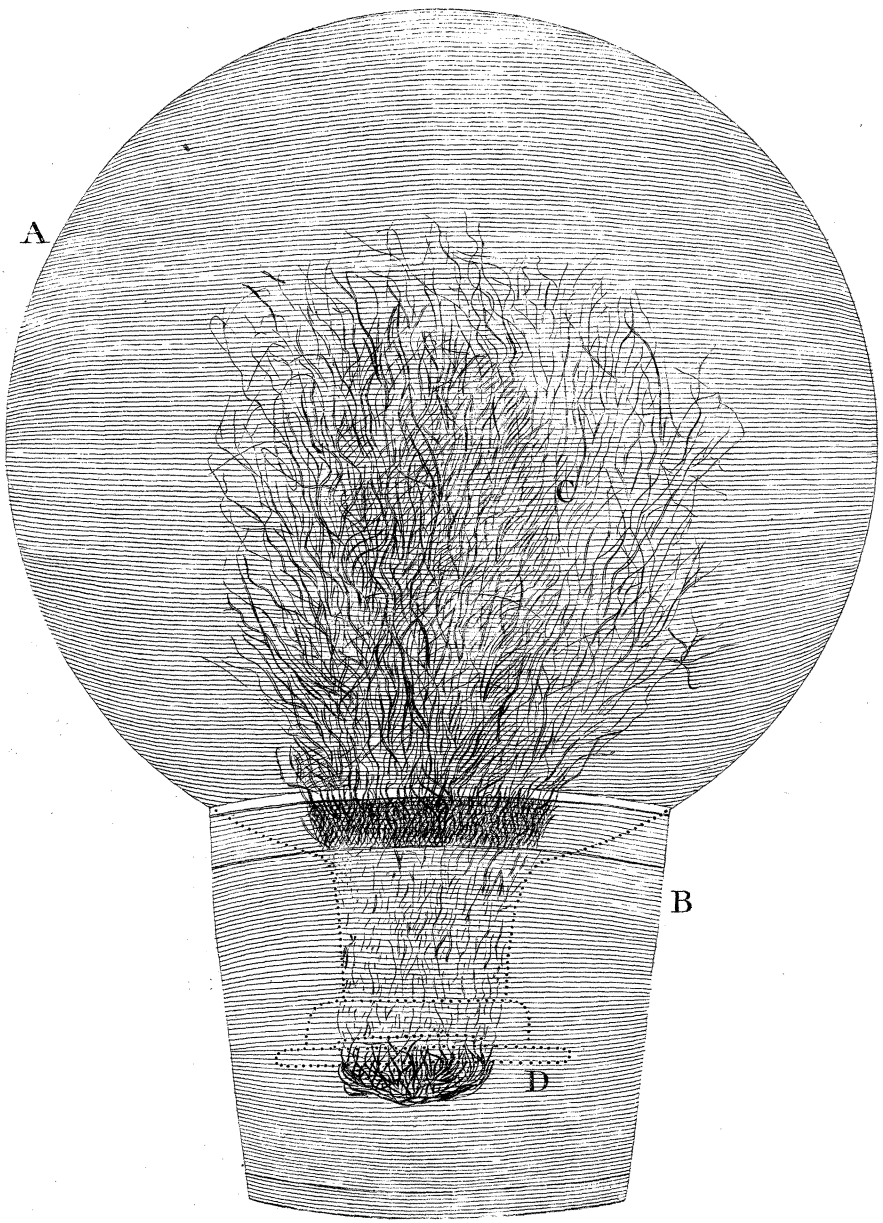
the metallic fluid in the tube, to allow the air within the tube to expand by the heat of the ſun without eſcaping. After this apparatus had ſtood during a few hours, in a bright ſun-ſhine, I cooled the whole to the ſame degree it poſſeſſed when it was expoſed to the ſun. This was done by plunging the whole in a tub filled with water, whoſe degree of heat was reſtored to the ſame degree it had before. I found the quantity of air within the tube remarkably increaſed, and ſo far dephlogiſticated that a flame burned in it with an increaſed brightneſs, and that one meaſure of it joined to one meaſure of nitrous air occupied 0.64; whereas the ſame air, before it was ſhut up with the *cereus* was of ſuch a degree of goodneſs, that one meaſure of it with one of nitrous occupied 1.06. Though this experiment may fully ſhew that plants throw out air in the ſun-ſhine, yet if another plant, which does not by nature yield ſo much air as the *cereus* commonly does, is ſhut up in a ſimilar tube, and expoſed to the ſun, the ſame effect will not always be obtained. The reaſon of it is, that plants abſorb a good quantity of common air as their nouriſhment at the ſame time that they throw out dephlogiſticated air. This fact, therefore, if conſidered by itſelf, will not be looked upon as equally demonſtrative with the above mentioned ones. The reſult of this experiment may depend on the more or leſs vigour of the vegetable employed, on the more or leſs brightneſs of the ſun's light, on the more or leſs heat the vegetable receives, &c. A *cereus* being a plant of hot climates may bear more heat than an European plant. All theſe circumſtances, as well as many others, may make the iſſue of this experiment ſometimes ambiguous; but the fact, as I have related it, joined to the above mentioned analogous experiments

of

of Dr. HALES and Mr. BOYLE, will add ſtrength to my aſſertion, *viz.* that vegetables really throw out air in the ſun-ſhine.

If all what I have ſaid hitherto ſhould not be thought ſufficient to take away the prejudice which Dr. PRIESTLEY's fifth volume, and Mr. CAVALLO's book on Air, may have produced in the mind of ſome philoſophers, I ſhould adviſe them to be preſent, at leaſt once, at the moſt beautiful ſcene which they will behold, when a leaf of an *agave Americana*, cut in two or three pieces, is immerſed in a glaſs bell or jar full of pump-water, inverted and expoſed to the ſun in a very fair day in the middle of the ſummer, when this plant is in its full vigour; and when they ſhall have ſeen thoſe beautiful and continual ſtreams of air, which ruſh from ſeveral parts of this vegetable, principally from the white internal ſubſtance of it, I will be anſwerable for their laying aſide all farther doubt about the truth of my doctrine.

After having now demonſtrated, as I think, in the cleareſt manner, that vegetables diffuſe through our atmoſphere, in the ſun-ſhine, a continual ſhower of this beneficial, this truly vital air; and that plants immerſed in water, far from robbing it of all air, impregnate it fully with a better and more ſalubrious air; let us not paſs ſo wonderful, and hitherto not even ſo much as ſuſpected, an operation of nature, without admiring the deſigns of that infinite wiſdom, who has employed ſuch hidden, ſuch wonderful, and at the ſame time ſuch beneficial means to preſerve from deſtruction the living beings which inhabit our earth; and let us conſider, whether it would not be worth while to attempt drawing ſome benefit from this new diſcovery, by making uſe of veſſels of water, in which ſome leaves of vegetables have been expoſed in the ſun-ſhine; by placing ſuch veſſels in our rooms; by ſtirring the water; by



A. *a globular glass vessel containing about 160 cubic inches of water.*
B. *glass vessel fill'd with Mercury in which the orifice of the spherical vessel is plunged.*
C. *a vegetable called Conferva rivularis.*
D. *a piece of wood to which the Conferva rivularis is attached to keep it in its place.*

ſprinkling with it our floors inſtead of uſing for this purpoſe common water; by placing within our houſes, inſtead of flower-pots, diſhes containing ſome *conferva rivularis*, a plant to be met with almoſt every where, ſhooting forth with the utmoſt luxuriancy in all water baſons, in all tubs and veſſels in which water is kept. Is it poſſible, after all this, not to believe, that the Creator has multiplied this vegetable with a ſimilar view to our benefit? This benefit we may now, with ſome confidence, apply to our preſervation, by honouring this vegetable with a place in thoſe of our own rooms which are expoſed to the ſun, and keeping it alive as long as we pleaſe; which may be done by only pouring every day freſh water upon it, and ſqueezing gently now and then out of it the dephlogiſticated air with which the whole maſs ſwells up almoſt as ſoon as the ſun caſts its rays upon it. The water itſelf, in which it has been immerſed, will now, perhaps, be looked upon as too precious to be thrown away as uſeleſs and deprived of that very principal of animal life, of which I have demonſtrated it to be highly pregnant.